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Genus-specific commensalism of the galeommatoid bivalve *Koreamya arcuata* (A. Adams, 1856) associated with lingulid brachiopods

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Abstract

We compared shell morphology and DNA sequences of the ectosymbiotic bivalves *Koreamya* (Montacutidae) attached to two different species of inarticulate brachiopods *Lingula* collected from South Korea. There are some differences in shell morphology between *K. arcuata* (A. Adams, 1856) attached to *Lingula anatina* and *K. sp.* attached to *L. adamsi*, such as shell outline, periostracum and hinge teeth. However, there are very few differences in DNA sequences of COI and ITS1 suggesting that the two forms of *Koreamya* are genetically conspecific. While many ectosymbiotic Galeommatoida species have been reported to live commensally with only one host species, this study suggested that *K. arcuata* lives commensally with at least two species of *Lingula* and that its shell morphology may vary according to the host species.

Key words: Galeommatoid bivalve, Ectosymbiosis, *Lingula*, Mitochondrial COI gene, Montacutidae, Nuclear ITS, Shell morphology, South Korea

Introduction

Ectosymbiotic bivalves of the superfamily Galeommatoida have already been reported from various invertebrate hosts such as Porifera, Coelenterata, Sipunculoidea, Echiuroidea, Bryozoa, Annelida, Mollusca, Arthropoda, Brachiopoda and Echinodermata (Boss 1965; Morton and Scott 1989; Kato 1998; Lützen *et al.* 2009). However, among them, only one species, *Koreamya arcuata* (A. Adams, 1856) has been recorded living commensally with a brachiopod. The hosts of *K. arcuata* are the inarticulate brachiopods *Lingula anatina* Lamarck, 1801 from South Korea (Hong *et al.* 2007; Lützen *et al.* 2009) and the Philippines (Savazzi 2001), *L. translucida* Dall, 1921 from SE India (Fernando and Fernando 1983) and *L. sp.* from Western Australia (Lützen *et al.* 2009). However, there are no studies comparing the shell morphology of the bivalves attached to different species of *Lingula* Bruguière, 1791 or investigating their DNA sequences.

In May 2003, we found a population of *Koreamya* Lützen, Hong & Yamashita, 2009 attached to *Lingula adamsi* Dall, 1873 on the southwestern coasts of South Korea (Sato *et al.* 2004). *Koreamya sp.* attached to *L. adamsi* is very similar to *K. arcuata* attached to *L. anatina* from South Korea, but Lützen *et al.* (2009) noted that the shells of *K. sp.* are generally smaller, thinner and more rounded than those of *K. arcuata*. In the present study, we collected more specimens of *Koreamya* from South Korean tidal-flats, and compared their shell morphology in detail and their DNA

sequences of mitochondrial cytochrome oxidase subunit I (COI) and nucleic internal transcribed spacer 1 (ITS1) to test whether or not two species can be recognized.

Materials and methods

Specimens of *Koreamya arcuata* attached to *Lingula anatina* (Fig. 1A) were collected from a sandy mud substratum in the middle intertidal zone of the following tidal-flats: Seondo-ri, Biin-myeon, Seocheon-gun, Chungcheongnam-do, (36° 08' 02" N, 126° 34' 36" E) (A in Fig. 2) on 3 April and 10 July 2008 (9 individuals, TUMC110962-110964); Sura, Okbong-ri, Okseo-myeon, Gunsan-si, Jeollabuk-do (35° 55' 55" N, 126° 36' 15" E) (B in Fig. 2) on 5 May, 2003 (3 individuals, JKTS 148); Geojeon, Simpo-ri, Jinbong-myeon, Gimje-si, Jeollabuk-do (35° 50' 36" N, 126° 41' 00" E) (C in Fig. 2) on 16 August 2002 and 25 September 2003 (29 individuals, TUMC110956-110958 and JKTS 141-147); Daehang-ri, Byeonsan-myeon, Buan-gun, Jeollabuk-do (35° 41' 15" N, 126° 31' 59" E) (D in Fig. 2) on 2 September 2007 (9 individuals, TUMC110959-110961); Seojeon, Hajeon-ri, Simwon-myeon, Gochang-gun, Jeollabuk-do (35° 32' 33" N, 126° 33' 54" E) (E in Fig. 2) on 27 March 2009 (3 individuals, TUMC110965); Waon, Sangnae-ri, Haeryong-myeon, Suncheon-si, Jeollanam-do (34° 51' 00" N, 127° 31' 16" E) (F in Fig. 2) on 30 April 2010 (20 individuals). Specimens of *Koreamya sp.* attached to *Lingula adamsi* (Fig. 1B) were collected from the middle to low intertidal zone of

the mud tidal-flats at Woldoo, Yongjeong-ri, Hyeongyeong-myeon, Muan-gun, Jeollanam-do (35° 04' 47" N, 126° 23' 49" E) (J in Fig. 2) on 8 April 2008 (15 individuals, TUMC110966–110969). Individuals of *Lingula* spp. were

dug up using a shovel at low tide, and the bivalves were removed from the shells of *Lingula* spp. and preserved in 99.5% ethanol.

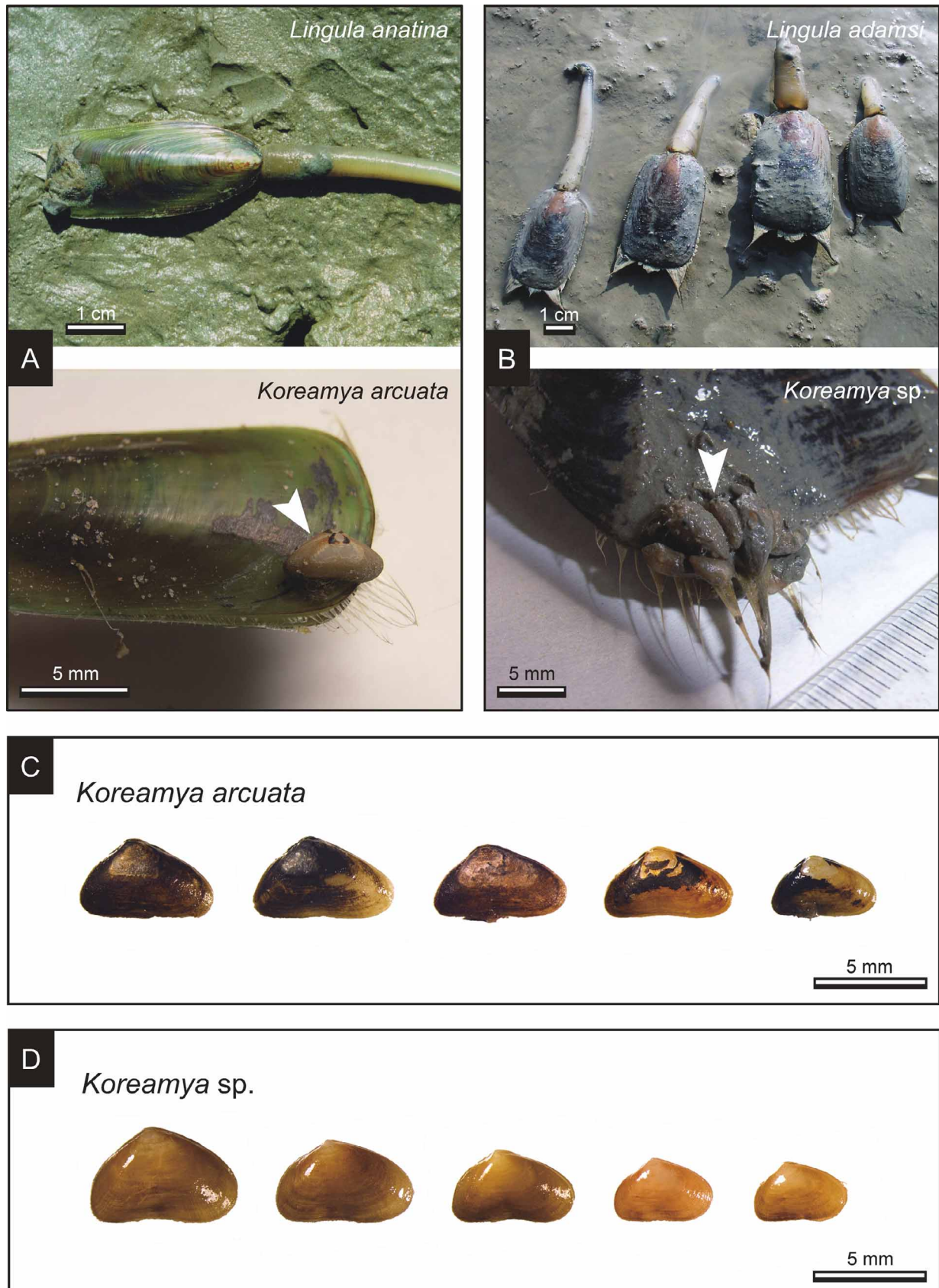


FIGURE 1. A. *Koreamia arcuata* attached to *Lingula anatina*. B. *Koreamia* sp. attached to *Lingula adamsi*. C. Shells of *Koreamia arcuata* (TUMC110962). D. Shells of *Koreamia* sp. (TUMC110969).



FIGURE 2. Distribution of *Koreamyia* in South Korea. A–I. *K. arcuata*. J. *K. sp.* ○ present population, × extinct population. A. Seondo-ri. B. Sura, Okpong-ri. C. Geojeon, Simpo-ri. D. Daehang-ri. E. Seojeon, Hajeon-ri. F. Woon, Sangnae-ri. G. Gaehwa-ri. H. Yubu-do Island. I. Deokgyo-dong. J. Woldoo, Yongjeong-ri.

Shell height (SH) and shell length (SL) in eight individuals from Seocheon-gun (A in Fig. 2) and 12 individuals from Gimje-si (C in Fig. 2) as *Koreamyia arcuata* and 14 individuals from Muan-gun (J in Fig. 2) as *K. sp.* were measured using a slide caliper (accuracy $\pm 0.05\text{mm}$). The height of the shell anterior margin (HA, see Fig. 4) was measured using image analysis software (Scion Image ver. 1.63, available as freeware) in nine individuals from Seocheon-gun, 20 individuals from Gimje-si as *Koreamyia arcuata* and 15 individuals from Muan-gun as *K. sp.* SL was analyzed with reduced major axis regression against SH, and HA were done in the same way against SL. The slopes and positions of reduced major axis regression were compared between the two forms using a significance test at 99% confidence level (Hayami and Matsukuma 1971). Nine shells coated with platinum (JEOL JFC-1600) and 11 uncoated shells were observed by scanning electron microscopes (JEOL JSM-T20, JSM-T330A or JSM-840A). We compared the shell morphology details in eight to 13 specimens of *K. arcuata* from three localities (Seocheon-gun, Gimje-si, Buan-gun) and six specimens of *K. sp.* from Muan-gun using a scanning electron microscope (SEM). The anatomy was examined using a stereoscopic microscope in five specimens of *K. arcuata* from Suncheon-si and three of *K. sp.* from Muan-gun.

TABLE 1. Amplification and sequencing primers for the COI and ITS1 regions. COI-F and COI-R were designed according to Matsumoto and Hayami (2000) and the others were anew. COI-D and COI-Dr were used only in DNA sequencing.

primer	5' — 3'
COI-F	ATYGGNGGNTTYGGNAAYTG
COI-R	ATNGCRAANACNGCNCCYAT
COI-D	TGRTTYTTYGGNCAYCCNGA
COI-Dr	TCNGGRTGNCCRAARAAYCA
ITS1-F	GGAAGTAAAAGTCGTAACAAGG
ITS1-R	CGATGTTCAATGTGTCTCTGCAAT

Total DNA was extracted from ethanol-preserved tissues of the samples of *K. arcuata* from Seocheon-gun and *K. sp.* from Muan-gun by DNeasy Blood and Tissue Kit (QIAGEN). COI and ITS1 regions were amplified by Premix Ex Taq and PCR thermal cycler PERSONAL (TaKaRa). The conditions of PCR amplification were denaturation (94 °C and 30 sec.), annealing (COI: 57 °C and 30 sec., ITS1: 58 °C and 30 sec.), extension (72 °C and 1 min.) for 25 cycles. The primers used in this study are shown in Table 1. PCR products were purified by ExoSAP-IT (GE Healthcare), and direct cycle sequencing was performed on 3130 Genetic Analyzer (ABI PRISM) in both directions using the BigDye Terminator v3.1 Cycle Sequencing Kit (ABI PRISM). These sequences were registered in the DNA Data Bank of Japan (Table 2).

TABLE 2. Accession numbers of investigated samples. TUMC110962-1 to 5: *Koreamyia arcuata* from Seondo-ri, Seocheon-gun. TUMC-110969-1 to 5: *Koreamyia sp.* from Woldoo, Yongjeong-ri, Muan-gun.

species	specimen	accession number	
		COI	ITS1
<i>Koreamyia arcuata</i>	TUMC110962-1	AB474955	AB499832
	TUMC110962-2	AB474956	AB499833
	TUMC110962-3	AB474957	AB499834
	TUMC110962-4	AB474958	AB499835
	TUMC110962-5	AB474959	AB499836
<i>Koreamyia sp.</i>	TUMC110969-1	AB474950	AB499827
	TUMC110969-2	AB474951	AB499828
	TUMC110969-3	AB474952	AB499829
	TUMC110969-4	AB474953	AB499830
	TUMC110969-5	AB474954	AB499831

Obtained sequences were aligned by CLUSTALW (Thompson *et al.* 1997). Maximum likelihood phylogenetic analyses of the COI sequences were conducted using PAUP* 4.0 beta 10 (Swofford 1998) comprising 1,000 bootstrap replicates. Models to be used in phylogenetic analyses were

estimated by using Modeltest version 3.7 (Posada and Crandall 1998), and the substitution model chosen was HKY+G. *Meretrix petechialis* (Lamarck, 1818) (accession number: EU145977) and *Ruditapes philippinarum* (Adams & Reeve, 1850) (accession number: AB244335; this study validates the genus *Ruditapes* Chiamanti, 1900 instead of *Venerupis* Lamarck, 1818) were used as the outgroup. The monophyly of *Koreameya arcuata* and *Koreameya* sp. was also tested by the SH-test (Shimodaira and Hasegawa 1999). The number of substitutions on the ITS1 sequences were also investigated.

Abbreviations: TUMC—Tohoku University Museum Collection, Sendai; JKTS—Japan/Korea Tidal Flat Joint Survey Group, Fujisawa.

Results

Distribution

In addition to the present study (see Materials and methods), *Koreameya arcuata* attached to *Lingula anatina* is recorded by Lützen *et al.* (2009) from Gaehwa-ri, Gaehwa-myeon, Buan-gun, Jeollabuk-do (35° 47'11" N, 126° 33'09" E) (G in Fig. 2), Yubu-do Island, Seochon-gun, Chungcheongnam-do (36° 00'20" N, 126° 37'55" E) (H in Fig. 2), and Deokgyo-dong, Jung-gu, Incheon (37° 25'58" N, 126° 24'59" E) (I in Fig. 2), South Korea. Therefore, *K. arcuata* associated with *L. anatina* is now known from nine localities, i.e. eight localities along the western coast and one on the southern coast of South Korea (A–I in Fig. 2). Three of these populations (Okpong-ri, Simpo-ri, Gaehwa-ri) have subsequently been lost to the Saemangeum Reclamation Project (Hong *et al.* 2007). *Koreameya* sp. attached to *Lingula adamsi* was recorded to date from only one locality (Muan-gun) on the southwestern coast of South Korea (J in Fig. 2).

Comparison of shell morphology and anatomy

Shell outlines of both *Koreameya arcuata* and *K. sp.* are subequilateral triangular and the anterior ends are long (Fig. 1C, Fig. 3A–D). The antero-dorsal and postero-dorsal margins of *K. arcuata* are nearly straight, whilst those of *K. sp.* are rather rounded (Fig. 3 A–D). Roundness of the antero-dorsal margin reflects the height of shell anterior margin (HA in Fig. 4). The slope of reduced major axis regression in HA against SL is not significantly different between *K. arcuata* and *K. sp.* ($K = 0.88$; $p > 0.05$), but their positions (the y-intercepts of reduced major axis regression) are significantly different ($K = 2.90$; $p < 0.01$) (Fig. 4). *K. arcuata* also seems more elongate than *K. sp.* (Fig. 3A–D), however the difference between SH and SL was not statistically significant ($K = 1.68$; $p > 0.05$, Fig. 5). In both forms, the posterior cardinal tooth of the right valve has a thickened spoon-like crest which on its inside is hollowed out by a shallow groove (Fig. 3G, H). However, the crest of the cardinal tooth of *K. sp.* is wider than *K. arcuata* (Fig. 3C, D, G, H). In *K. arcuata*, the anterior elongate lateral tooth of the right valve is narrow and straight, but in *K. sp.* it is rather wide and slightly curved (Fig. 3E, F).

The prodissococonch II in two specimens of *K. arcuata* measures $464 \times 291 \mu\text{m}$ (SL \times SH) and $610 \times 362 \mu\text{m}$ (SL \times SH; Fig. 6C), and one from a juvenile *K. sp.* measures $414 \times 303 \mu\text{m}$ (SL \times SH; Fig. 6D). The shell surface and periostracum of *K. arcuata* is heavily corroded from the umbo to the center during growth (Fig. 6A), in contrast to *K. sp.*, in which corrosion was less and the periostracum covered the umbo even in the adult shell (Fig. 6B). The periostracum of *K. arcuata* is dark brownish and thick, while that of *K. sp.* is light brownish, glossy and thinner (Fig. 1). In both forms, the periostracum is ornamented with narrow discontinuous lamellae width *ca.* 20–30 μm (Fig. 6H). There are no radial ribs on the outermost shell surface, whilst many periostracal striae form a lattice pattern crossing with commarginal periostracal lamellae (Fig. 6E, F, H). The spaces between each periostracal lamella in *K. arcuata* are filled by many grains of sediment (Fig. 6G).

Gross anatomical features of *K. sp.* were identical with those of *K. arcuata* as reported by Lützen *et al.* (2009). *K. arcuata* associated with *L. anatina* had consistently the same shell characters in all the nine surveyed populations in South Korea. Because *K. sp.* on *L. adamsi* was known from only one locality, only its intrapopulation variation could be assessed.

Analyses of DNA sequences

Sequencing of COI and ITS1 regions yielded 903 and 524 bp, respectively, from 10 investigated individuals. The heterozygosity of COI and ITS1 was not observed. In the COI sequences, there were 4–16 bp (0.4–1.7 %) nucleotide differences; the maximum number of intraform was 12 bp on Muan-gun and 14 bp on Seochon-gun, respectively, and that of interform was 16 bp. However, there were no differences between them in inferred amino acid sequences due to synonymous substitutions. In the ITS1 sequences, nucleotide differences were 0–1 bp (0–0.2 %); the maximum number of intra- and interform was 1 bp together. The maximum likelihood phylogenetic tree for the COI data showed that both *Koreameya arcuata* and *Koreameya* sp. were polyphyletic ($-\ln L = 2960.546$) (Fig. 7). However, the SH-test did not reject monophyly of each form ($\Delta -\ln L = 14.628$; $p > 0.05$).

Discussion

Some differences in shell morphology exist between *Koreameya arcuata* attached to *Lingula anatina* and *Koreameya* sp. attached to *L. adamsi*, such as shell outline, teeth and periostracum (Figs 1, 3, 4, 6). However, DNA sequences of COI and ITS1 revealed that there are very few differences between the two forms suggesting that *K. arcuata* and *K. sp.* are genetically similar and probably the same species (Fig. 7). If they are indeed conspecific, these findings suggest that *K. arcuata* can live commensally with two different species of *Lingula*, and the shell morphology may vary according to the host species. The shell of *Lingula adamsi* (adult dorsal shell length *ca.* 60 mm) is much larger than that of *L. anatina* (*ca.* 35 mm). The maximum dorsal

shell length of the former may exceed 70 mm (Sato *et al.* 2004), and its burrow is much larger than that of *L. anatina*. Most individuals of *L. anatina* were collected from sandy mud bottom, but *L. adamsi* was only collected from mud

tidal-flats. The shell morphology in *K. arcuata* may be influenced by differences between the two host species such as shell size, life history traits, and habitats.

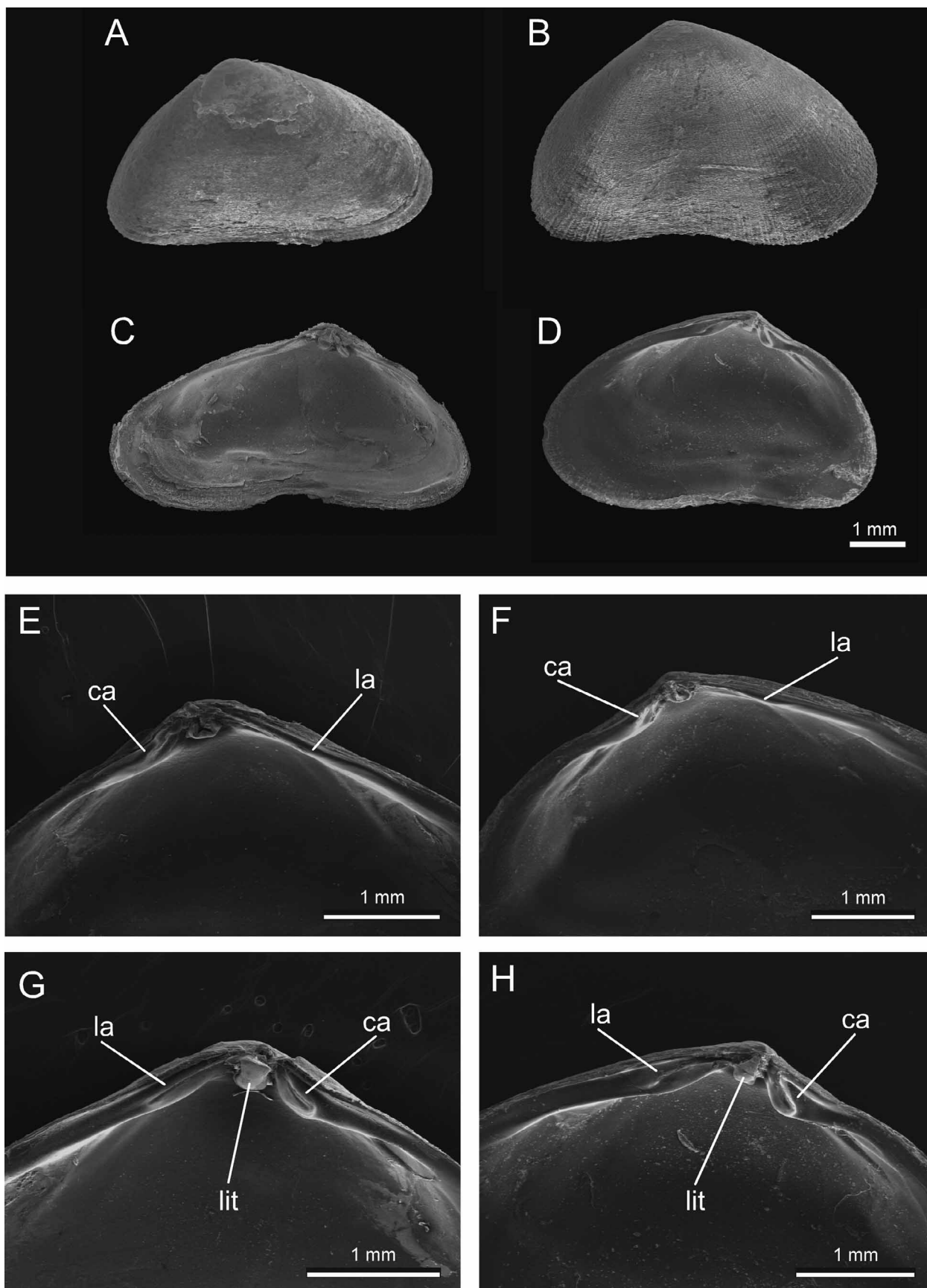


FIGURE 3. SEM images of the shell and hinge of *Koreameya*. **A, C, G.** Right valve of *Koreameya arcuata*. **E.** Left valve of *K. arcuata*. **B, D, H.** Right valve of *K. sp.* **F.** Left valve of *K. sp.* ca, cardinal tooth; la, lateral tooth; lit, lithodesma.

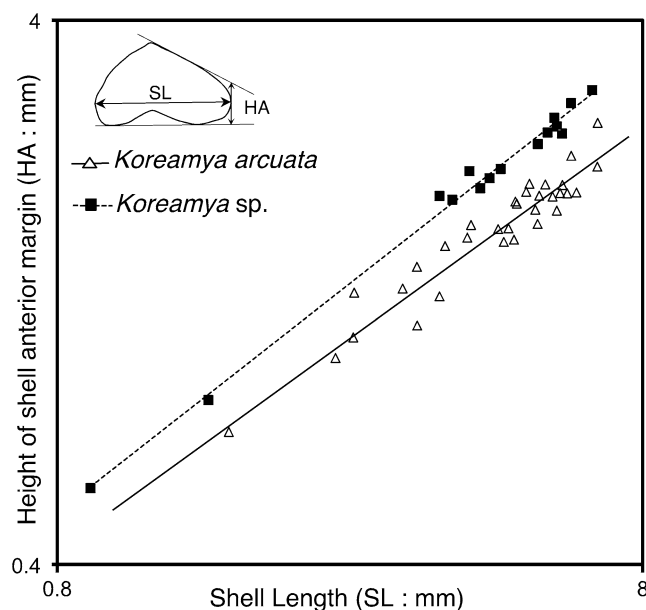


FIGURE 4. Plots of log-transformed height of shell anterior margin (HA: mm) against log-transformed shell length (SL: mm) with reduced major axis regression for *Koreameya arcuata* ($HA = 0.598 SL^{0.845}$) and *Koreameya* sp. ($HA = 0.491 SL^{0.805}$).

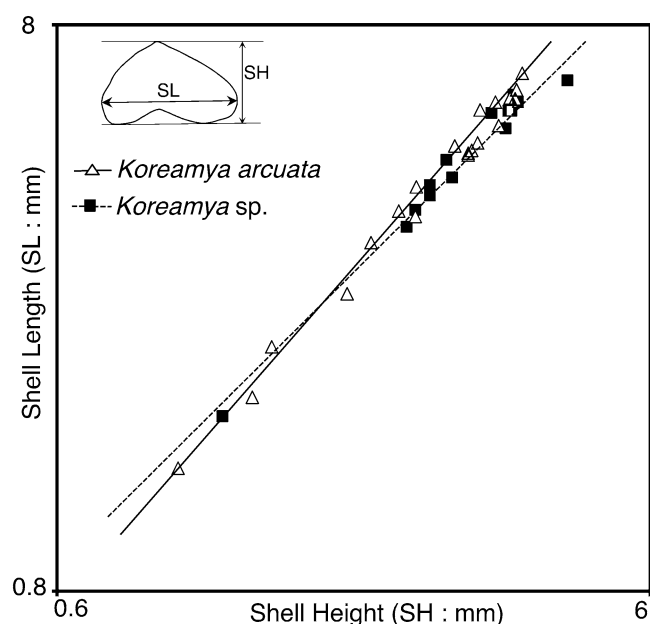


FIGURE 5. Plots of log-transformed shell length (SL: mm) against log-transformed shell height (SH: mm) with reduced major axis regression for *Koreameya arcuata* ($SL = 1.380 SH^{1.174}$) and *Koreameya* sp. ($SL = 1.446 SH^{1.089}$).

There are many ectosymbiotic species among the Galeommatoidea. Most of these are reported to live commensally with only a single host species. However, some species have been confirmed to be associated with several host species. Among the ectosymbiotic galeommatooid species collected from Japan, Korea and China, 23 species are reported to attach directly on the body or shell of only one host species, while six species (*Pseudopythina macrophthalmenensis* Morton and Scott, 1989, *Montacuta*

echinocardiophila Habe, 1964, *Koreameya arcuata*, *Nipponomysella subtruncata* (Yokoyama, 1922), *Peregrinamor ohshimai* Shoji, 1938 and *Curvemysella paula* (Adams, 1856)) have been demonstrated to live with several species (Table 3). One of these species, *N. subtruncata*, has been reported to live with two different host species, *Siphonosoma cumanense* (Keferstein, 1867) and *Sipunculus nudus* Linnaeus, 1766, but the latter is now considered a misidentification of *S. cumanense*. For example, Habe (1970) misidentified *S. cumanense* as *S. nudus* in his Plate 1, and subsequent authors have followed the misidentification (Table 3). The host of *N. subtruncata* in the figures of Matsukuma (2000), Hamamura (2004) and Aichi Environmental Research Center (2009) are identified as *S. cumanense*, but there is no photographic evidence of *N. subtruncata* living commensally with *S. nudus* in the literature. *N. subtruncata* living commensally with *S. cumanense* has been found from six localities in Japan (Hiroshima, Yamaguchi, Oita, Saga, Kumamoto and Okinawa Prefectures; H. Yamashita, unpublished data).

Three species (*Ps. macrophthalmenensis*, *Pe. ohshimai* and *K. arcuata*) are now known to live commensally with multiple host species belonging to the same genus (*Macrophthalmus* Desmarest, 1823, *Upogebia* Borradaile, 1903, and *Lingula*, respectively). The present study has revealed that *K. arcuata* is in a genus-specific commensal relationship with *Lingula anatina* (Savazzi 2001; Lützen *et al.* 2009), *L. adamsi* (the present study), and most probably with *L. translucida* (Fernando and Fernando 1983) and *L. sp.* (Lützen *et al.* 2009). *K. arcuata* is, however, exceptional in that it is the only ectosymbiotic galeommatooid species in which shell morphology is known to differ between populations from the different host species.

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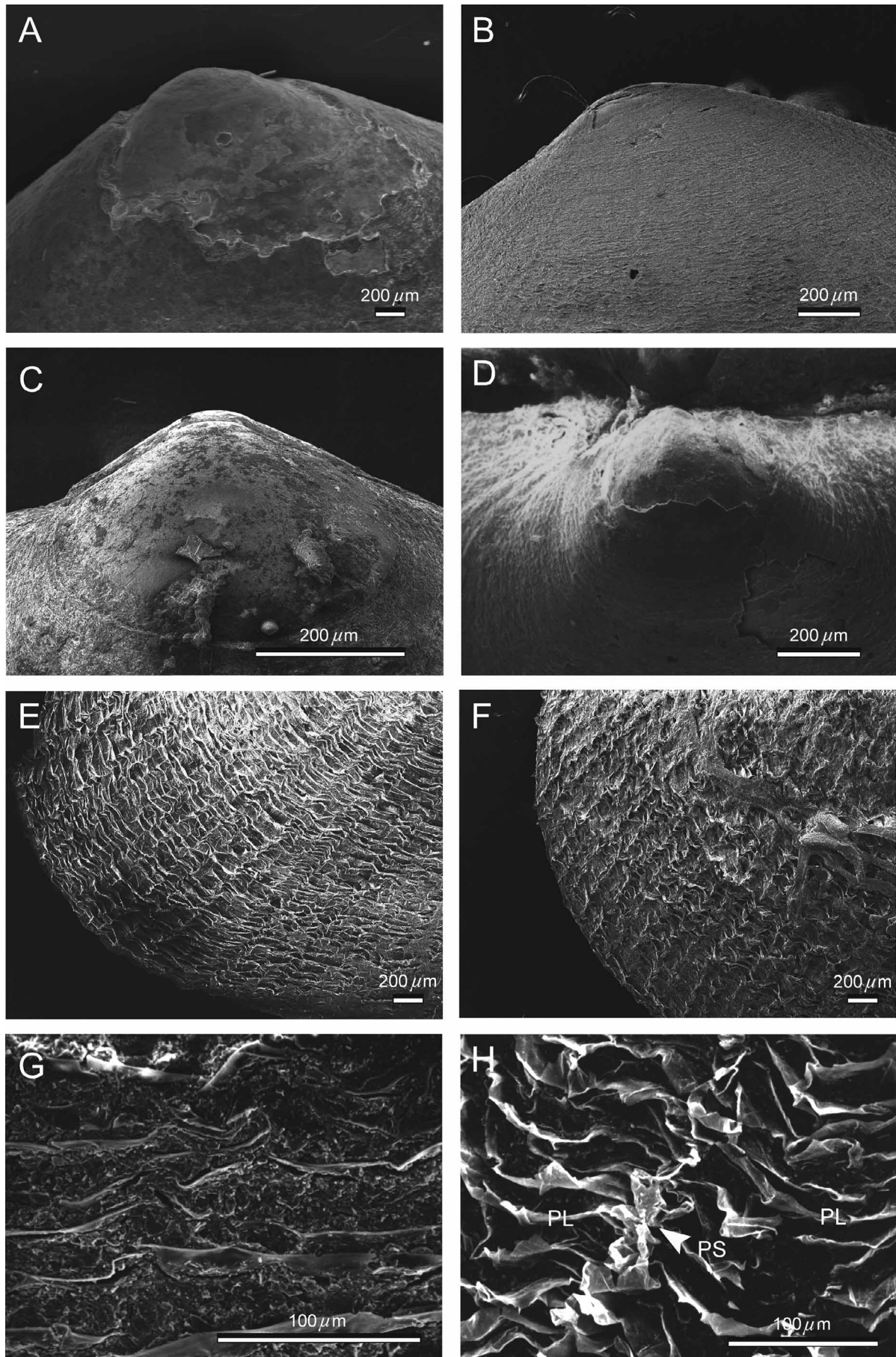


FIGURE 6. SEM images of the shell and prodissococonch of *Koreameya*. **A, C, E, G.** *Koreameya arcuata*. **B, D, F, H.** *K. sp.* **A, B, C, D.** Umbo and prodissococonch of right valve. **E, F, G, H.** Periostracum. PL, periostracal lamella; PS, periostracal stria.

TABLE 3. Partial list of ectosymbiotic galeommatoid species and their hosts recorded from Japan, Korea and China.

Family	Galeommatoid bivalve		Host animal		References
	species	No. of Host species	species	taxon	
Lasacidae	<i>Litigiella pacifica</i> Lützen & Kosuge, 2006	1	<i>Sipunculus nudus</i> Linnaeus, 1799	Sipuncula	Lützen & Kosuge 2006
Lasacidae	<i>Salpocoda philippinensis</i> Habe & Kanazawa, 1981	1	<i>Sipunculus nudus</i> Linnaeus, 1799	Sipuncula	Habe & Kanazawa 1981; Kosuge & Kubo 2002; Lützen <i>et al.</i> 2008
Leptonidae	<i>Arthritica japonica</i> Lützen & Takahashi, 2003	1	<i>Xenophthalmus pimotheroideus</i> White, 1846	Arthropoda	Lützen & Takahashi 2003
Kellidae	<i>Pseudopythina ariakensis</i> (Habe, 1959)	1	<i>Protankyra bidentata</i> (Woodward & Barret, 1858)	Echinodermata	Morton & Scott 1989
Kellidae	<i>Pseudopythina macrophthalmenensis</i> Morton & Scott, 1989	6	<i>Macrophthalmus latreillei</i> (Desmarest, 1822)	Arthropoda	Morton & Scott 1989; Bernard <i>et al.</i> 1993; Higo <i>et al.</i> 1999
			<i>Macrophthalmus convexus</i> Stimpson, 1898	Arthropoda	Kosuge & Itani 1994; Jespersen <i>et al.</i> 2001
			<i>Macrophthalmus milloti</i> Crosnier, 1965	Arthropoda	Kosuge 2005
			<i>Macrophthalmus brevis</i> (Herbst, 1804)	Arthropoda	Kosuge 2005
			<i>Macrophthalmus serenei</i> Takeda & Komai, 1991	Arthropoda	Hayase <i>et al.</i> 2009
			<i>Macrophthalmus telescopius</i> (Owen, 1839)	Arthropoda	Yamashita <i>et al.</i> 2005
Kellidae	<i>Pseudopythina maipoensis</i> Morton & Scott, 1989	1	<i>Discapseudes</i> sp.	Arthropoda	Morton & Scott 1989; Bernard <i>et al.</i> 1993
Kellidae	<i>Pseudopythina nodosa</i> Morton & Scott, 1989	1	<i>Sipunculus nudus</i> Linnaeus, 1799	Sipuncula	Morton & Scott 1989
Kellidae	<i>Pseudopythina ochetostomae</i> Morton & Scott, 1989	1	<i>Ochetostoma erythrogrammon</i> Leuckart and Rüppell, 1828	Echiura	Morton & Scott 1989; Bernard <i>et al.</i> 1993; Jespersen <i>et al.</i> 2002
Kellidae	<i>Pseudopythina tsurumaru</i> (Habe, 1959)	1	<i>Protankyra bidentata</i> (Woodward & Barret, 1858)	Echinodermata	Morton & Scott 1989; Lützen <i>et al.</i> 2004
Kellidae	<i>Pseudopythina substimata</i> (Lischke, 1871)	1	<i>Squilla oratoria</i> De Haan, 1844	Arthropoda	Habe 1977; Morton & Scott 1989; Higo & Goto 1993; Bernard <i>et al.</i> 1993; Higo <i>et al.</i> 1999; Jespersen <i>et al.</i> 2009; Yamashita unpublished data
Montacutidae	<i>Barrimystia siphonosomae</i> Morton & Scott, 1989	1	<i>Siphonosoma cumanense</i> (Kefenstein, 1867)	Sipuncula	Morton & Scott 1989; Bernard <i>et al.</i> 1993; Jespersen <i>et al.</i> 2002
Montacutidae	<i>Brachiomystia stigmatica</i> (Pilsbry, 1921)	1	<i>Brissus latecarinatus</i> (Leske, 1778)	Echinodermata	Yamamoto & Habe 1974; Ishikawa 1979; Higo & Goto 1993; Higo <i>et al.</i> 1999; Matsukuma 2000
Montacutidae	<i>Curvemysella paula</i> (Adams, 1856)	2	<i>Diogenes edwardsii</i> (De Haan, 1849)	Arthropoda	Morton & Scott 1989; Tanaka 1991; Goto <i>et al.</i> 2007
			<i>Spiropogonurus spiriger</i> (De Haan, 1849)	Arthropoda	Goto <i>et al.</i> 2007
Montacutidae	<i>Devonia semperi</i> (Ohshima, 1930)	1	<i>Protankyra bidentata</i> (Woodward et Barret, 1858)	Echinodermata	Ohshima 1930; Habe 1977; Higo & Goto 1993; Bernard <i>et al.</i> 1993; Higo <i>et al.</i> 1999
Montacutidae	<i>Anisodemonia oshimai</i> (Kawahara, 1942)	1	<i>Leptosynapta ooplax</i> (von Marenzeller, 1882)	Echinodermata	Kawahara 1942; Habe 1977; Higo & Goto 1993; Kato 1998; Higo <i>et al.</i> 1999; Lützen <i>et al.</i> 2005
Montacutidae	<i>Entovalva lessonothuriae</i> Kato, 1998	1	<i>Holothuria</i> (<i>Lessonothuria</i>) <i>pardalis</i> Selenka, 1867	Echinodermata	Kato 1998; Lützen <i>et al.</i> 2005
Montacutidae	<i>Fronsella ohshimai</i> Habe, 1958	1	<i>Sipunculus nudus</i> Linnaeus, 1799	Sipuncula	Habe 1958, 1977; Higo & Goto 1993; Higo <i>et al.</i> 1999

Table 3. continued.

Family	Galeommatoid bivalve		Host animal		References
	species	No. of Host species	species	taxon	
Montacutidae	<i>Koreamya arcuata</i> (A. Adams, 1856)	4	<i>Lingula anatina</i> (Lamarck, 1801) <i>Lingula adamsi</i> Dall, 1873 <i>Lingula transuecida</i> Dall, 1920 <i>Lingula</i> sp.	Brachiopoda Brachiopoda Brachiopoda Brachiopoda	Hong <i>et al.</i> 2007; Lützen <i>et al.</i> 2009; the present study Sato <i>et al.</i> 2004; Lützen <i>et al.</i> 2009; the present study Fernando & Fernando 1983 Lützen <i>et al.</i> 2009
Montacutidae	<i>Montacuta dhvaricata</i> Gould, 1861	1	<i>Schizaster lacunosus</i> (Linnaeus, 1758)	Echinodermata	Habe 1977; Higo & Goto 1993; Higo <i>et al.</i> 1999
Montacutidae	<i>Montacuta echinocardiophila</i> Habe, 1964	2	<i>Echinocardium cordatum</i> (Pennant, 1777) <i>Lovenia elongata</i> (Gray, 1845)	Echinodermata Echinodermata	Habe 1964, 1977; Higo & Goto 1993; Higo <i>et al.</i> 1999; Matsukuma 2000 Komatsu 1986; Higo & Goto 1993; Higo <i>et al.</i> 1999
Montacutidae	<i>Montacutona mutsuwanensis</i> Yamamoto & Habe, 1959	1	<i>Cerianthus filiformis</i> Carlgren, 1893	Cnidaria	Bernard <i>et al.</i> 1993; Higo <i>et al.</i> 1999
Montacutidae	<i>Nipponomontacuta acitnariophila</i> Yamamoto & Habe, 1961	1	<i>Halcampella maxima</i> Hertwig, 1888	Cnidaria	Yamamoto & Habe 1961; Habe 1973, 1977; Higo & Goto 1993; Matsukuma 2000
Montacutidae	<i>Nipponomysella oblongata</i> (Yokoyama, 1922)	1	<i>Ophioplocus japonicus</i> H. L. Clark, 1911	Echinodermata	Yamamoto & Habe 1959; Habe 1977; Higo & Goto 1993; Higo <i>et al.</i> 1999; Matsukuma 2000
Montacutidae	<i>Nipponomysella subtruncata</i> (Yokoyama, 1927)	2	<i>Sipunculus nudus</i> Linnaeus, 1799 <i>Siphonosoma cumanense</i> (Keferstein, 1867)	Sipuncula Sipuncula	Habe 1970, 1977; Oyama 1973; Higo & Goto 1993; Higo <i>et al.</i> 1999; Matsukuma 2000 Inaba 1982; Higo & Goto 1993; Higo <i>et al.</i> 1999; Lützen <i>et al.</i> 2001b; Hamamura 2004; Aichi Environmental Research Center 2009
Montacutidae	<i>Peregrinamor gastrochaenans</i> Kato & Itani, 2000	1	<i>Upogebia carinicauda</i> (Stimpson, 1860)	Arthropoda	Kato & Itani 2000; Itani 2002
Montacutidae	<i>Peregrinamor ohshimai</i> Shoji, 1938	6	<i>Upogebia major</i> (de Haan, 1841) <i>Upogebia issaeffi</i> (Balss, 1913) <i>Upogebia natutensis</i> Sakai, 1986 <i>Upogebia yokoyai</i> Makarov, 1938 <i>Upogebia pugnax</i> de Man, 1905 <i>Upogebia trispinosa</i> Sakai, 1991	Arthropoda Arthropoda Arthropoda Arthropoda Arthropoda Arthropoda	Shoji 1938; Higo & Goto 1993; Bernard <i>et al.</i> 1993; Sakai <i>et al.</i> 1995; Kato & Itani 1995, 2000; Higo <i>et al.</i> 1999; Lützen <i>et al.</i> 2001a; Itani <i>et al.</i> 2002 Horikoshi 1994 (in Sakai <i>et al.</i> 1995); Sakai <i>et al.</i> 1995; Higo <i>et al.</i> 1999; Kato & Itani 2000 Kato & Itani 2000; Itani 2002 Horikoshi 1994 (in Sakai <i>et al.</i> 1995); Kato & Itani 2000; Itani 2002 Itani 2002
Montacutidae	<i>Tellimya torishimensis</i> Callomon, 1999	1	<i>Lovenia</i>	Echinodermata	Okutani 1962; Higo <i>et al.</i> 1999
Galeommatidae	<i>Sagamiscintilla thalassemicola</i> (Habe, 1962)	1	<i>Anelassorhynchus mucosus</i> (Ikeda, 1904)	Echiura	Habe 1962, 1977; Higo & Goto 1993; Higo <i>et al.</i> 1999
Galeommatidae	<i>Scintillona brissae</i> Morton & Scott, 1989	1	<i>Brissus latecarinatus</i> (Leske, 1778)	Echinodermata	Morton & Scott 1989; Bernard <i>et al.</i> 1993

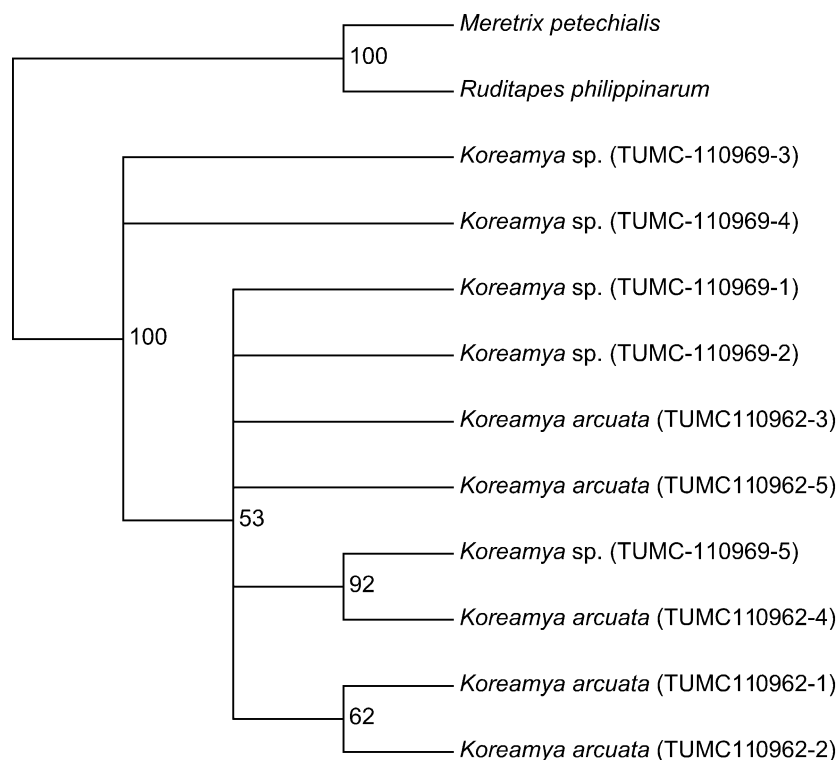


FIGURE 7. Maximum likelihood phylogenetic tree of *Koreameya arcuata* and *Koreameya* sp. inferred from COI sequence data. The numbers on the nodes indicate the bootstrap value.

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